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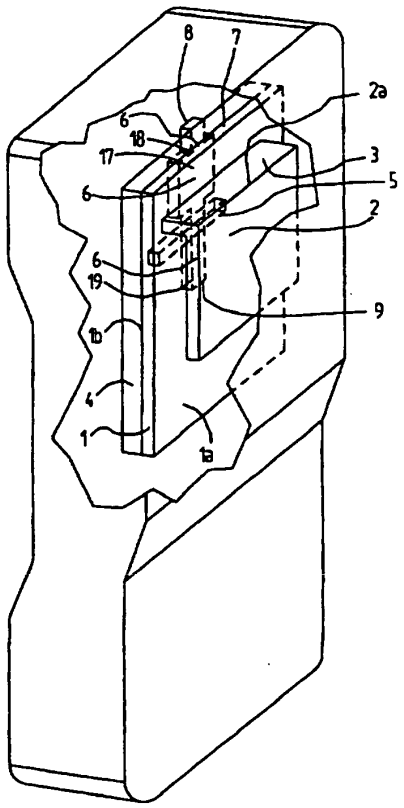
(54) Title: PLANAR ANTENNA DEVICE

(57) Abstract

A compact antenna device which is intended for a small-size portable radio communication device and comprises a ground plane (1), a first radiating patch (2), a grounding means (3) connecting the patch and the ground plane. The patch is fed by a feeding means (6) which is situated on the same or opposite side of the ground plane or coplanar therewith and couples through a slot (5) provided in the ground plane. The disclosed antenna device may include further radiating patches in the same or higher levels as the first radiating patch. The antenna device also provides for wideband and/or multiband operation.



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PLANAR ANTENNA DEVICE

FIELD AND BACKGROUND OF THE INVENTION

The invention relates to a planar antenna device according to the introductory portions of the independent claims. Specifically, it relates to an aperture-coupled planar antenna device for a mobile radio communication device, e.g., a hand-portable telephone. The invention further relates to this type of antenna which is intended for operation within two separated frequency bands.

PRIOR ART

US 5,355,143 discloses an antenna device wherein a half wave patch radiating element is mounted on a dielectric carrier spaced on a first side from and parallel to a ground plane which is provided with a slot. On a second side of the ground plane there is provided a feeding probe which feeds the patch by coupling energy through the slot. The ground plane, the feeding probe, and a conductive plate together form a strip-line. The teachings of that document are directed towards an antenna array and the antenna devices thereof are excessively large when integration in portable radio communication equipment is considered.

US 5,365,246 discloses another antenna device consisting of two parallel elongated L-shaped radiating elements which are parallel to and mounted in one end to a ground portion and which are fed by one or two probes. Those radiating elements have a slot between them which has a smaller width at free ends of the elements. That antenna device is more suited for portable equipment, but it has the disadvantage of a complicated design with regard to the feeding probes. However, that document is regarded to disclose the prior art closest to the invention.

The above-mentioned documents are incorporated herein by

reference.

SUMMARY OF THE INVENTION

A main object of the invention is to provide a compact antenna device with high antenna performance which is suited for production in large quantities.

A particular object of the invention is to provide an antenna device which may be integrated in a portable radio device, e.g., small-size mobile telephone.

Another object is to provide an antenna device with improved bandwidth and matching features.

Other objects of the invention are to provide a dual or multi band antenna device, to provide an antenna device which is capable of directing the radiation away from the body of an operator so as to avoid radiation absorption in the body, and to provide very short radiating structures in relation to the wavelength.

These and other objects are attained by an antenna device according to the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a perspective view of a mobile telephone provided with a first general embodiment of an antenna device according to the invention including a ground plane having a slot aperture, a radiating plate grounded along one edge, and a feed conductor.

Figs. 2A-E show views of the first general embodiment according to the invention including conductive plates, grounding means, a slot, a dielectric, and a feed conductor.

Fig. 3 shows in an exploded view parts of the antenna device of figs 2A-E.

Figs. 4A-K show different embodiments and variations of the

radiating patch of fig. 3.
Figs. 5A-C show different embodiments and variations of the ground plane of fig. 3.
Figs. 5D-E show an embodiment and variations thereof wherein the ground plane and feed conductor of fig. 3 are integrated.
Figs. 6A-B show L-element variations of the embodiments.
Figs. 6C-E show F-element variations of the embodiments.
Figs. 6F-I show T-element variations of the embodiments.
Figs. 6J-L show stacked T-element variations of the embodiments.
Figs. 6M-N show G-structure variations of the embodiments.
Figs. 7A-F show alternative feed arrangements of the embodiments.
Figs. 8A-D are perspective views of an embodiment according to the invention, with alternative feeding arrangements and variations thereof.
Figs. 9A-E illustrate an embodiment according to the invention, of an antenna device with a radiating slot, and variations thereof.
Figs. 10A-C illustrate embodiments according to the invention, of an antenna device provided with capacitances in order to reduce the dimensions.

DESCRIPTION OF A PREFERRED EMBODIMENT

With reference to fig. 1, a small-size mobile telephone is provided at its back side, preferable at a portion in which an operator is not typically gripping the telephone, with an antenna device according to the invention. The antenna device, which is preferably mounted inside and parallel to a non-conductive chassis wall of the telephone, includes a conductive ground plane or conductive first plate 1 having an outer side 1a and an inner side 1b, a radiating patch or conductive second plate 2 parallel to the ground plane 1, a grounding means 3 connecting the patch 2 to the outer side 1a of the ground plane 1 along one edge of the radiating patch 2. A slot aperture 5 is provided in the ground plane under the patch 2 in the proximity of and alongside the grounding means 3. On the inner side 1b,

there is provided a dielectric plate 4 which carries the ground plane on the one side and a feeding conductor 6 on the other.

The feeding conductor 6 extends across the slot 5, perpendicular to the slot 5 and to the grounded edge 2a of the patch 2. The feeding conductor 6 consists in order of a feed portion 8 which is connected to telephone circuitry (not shown), a first line portion 18, a quarter-wave transformer 17 for matching the impedance of the antenna to a standardized impedance of the circuitry (50 ohms), and a second line portion 19 extending across the slot 5 by essentially one quarter of a wavelength and ending by an open end 9. Alternatively the feeding conductor 6 is connected to the ground plane 1 at its end 10 directly after extending across the slot 5. In this way, an effective feed of the patch 2 is attained. However, there are many alternative configurations of the aperture and the feed line. The ground plane 1 is also connected at a feeding portion 7 thereof to the telephone circuitry.

For clarity, figs. 2 and 3 show details, having corresponding reference numerals, and views of the antenna device described with reference to fig.1.

In figs. 8A-D antenna devices, according to the invention are shown in perspective views. Each of these antenna devices includes a conductive ground plane or conductive first plate 1 having an outer side 1a and an inner side 1b, a radiating patch or conductive second plate 2 at a distance from the ground plane 1, and a grounding means 3 connecting the patch 2 to the outer side 1a of the ground plane 1 along one edge 2a of the radiating patch 2. A slot aperture 5 is provided in the ground plane under the patch 2 in the proximity of and alongside the grounding means 3. On the outer side 1a there is also provided a dielectric plate 4 which carries a feeding conductor 6. The dielectric plate covers the ground plane 1 or parts thereof in order to provide insulation between the ground plane 1 and the feeding conductor 6.

The feeding conductor 6 extends across the slot 5, preferably perpendicular to the slot 5 and to the grounded edge 2a of the patch 2. The feeding conductor 6 includes in order, a feed portion 8 which is connected to telephone circuitry (not shown), a first line portion 18, preferably a device 17 (quarter-wave transformer) for matching the impedance of the antenna to a standardized impedance of the circuitry, a second line portion 19 extending across the slot 5, and an open end 9, preferably at a distance from the aperture of approximately one quarter of a wavelength, of the signal which is to be transmitted or is received by the antenna device. Alternatively the feeding conductor 6 is connected to the grounding means 3 or the ground plane at its end 10 directly after extending over the slot 5. In this way, an effective feed of the patch 2 is attained. However, there are many alternative configurations of the aperture and the feed line. The ground plane 1 is also connected at a feeding or grounding portion 7 thereof to the telephone circuitry.

Referring to fig. 8A, the end 10 of the feeding conductor 6 is electrically connected to the grounding means 3 or the ground plane 1.

As illustrated in fig. 8 B, the grounding means 3 is provided with an opening 31 through which the feeding conductor extends. The opening 31 shall be of such a size that there will be no electrical contact between the feeding conductor 6 and the grounding means 3. The space between the grounding means 3 and the feeding conductor 6 in the opening 31 can be filled with an insulating material.

As illustrated in fig. 8C the feeding conductor 6 is bent in a U-shape 36 at its end 9 in order to achieve the desired length between the slot 5 and the end. The end 9 is an open end.

The antenna device illustrated in fig. 8D is similar to the antenna device in fig. 8A with the difference that it is fed from the opposite side, i.e. the feeding conductor 6 extends

from the feed portion 8 through the grounding means 3 and thereafter across the slot. Its end 9, 10 can be free or connected to the ground plane 1. It could also be provided with an U-shaped end which is open.

In the operation as a transmitting antenna, the feeding conductor 6 will excite the aperture 5, creating an electromagnetic filed across the aperture 5. For best efficiency it is desired that the feeding conductor 6 has a current maximum over the aperture. This is achieved by choosing an optimal length of the feeding conductor 6 between the aperture 5 and its end 9. This length is preferred to be approximately one quarter of the actual wavelength in all the embodiments with an open end. Alternatively a current maximum over the aperture can be achieved by connecting the feeding conductor to the ground plane 1 or the grounding means 3 at its end 10 directly after extending over the aperture 5. An electromagnetic field is then created between the ground plane 1 and the patch 2 (or conductive second plate). This field travels towards the free end 2b of the patch, where the antenna radiates in a direction essentially perpendicular to ground plane 1 and the patch 2.

Although embodiments have been described, having one feeding conductor 6 on either the outer side 1a or the inner side 1b of the ground plane 1, an antenna device according to the invention could include two or more feeding conductors 6, with preferably at least one feeding conductor 6 one each side. They are possibly exciting separate aperture slots, arranged e.g. as described in connection to figs. 5B-C, 6F-L and 6N. The feeding portions 8 can then be placed at or near different edges or the same edge of the ground plane 1.

Fig. 9A is a cross sectional view of an embodiment of an antenna device according to the invention. A ground plane 1 is provided with a slot aperture 5, preferably in the centre of the plane. Two grounding means 33, 3 are connected to the ground plane 1 at a first side 1a along two opposed edges

thereof. Two conductive plates 32, 2 are connected to the grounding means 33, 3 respectively, at edges opposed to the edges connected to the ground plane. Thereby the grounding means 33, 3 interconnect the plates 32, 2 and the ground plane 1. The plates 32, 2 extend towards each other, from the respective grounding means 33, 3, and end at edges 37, 38, respectively. The edges 37 and 38 limit a radiating slot 34.

Between the ground plane 1 and the plates 32, 2 there is a metallic layer or conductive plate 35 arranged, preferably parallel to and at the same (or approximately the same) distance L6 from the ground plane 1 and the plates 32, 2. The metallic layer or conductive plate 35 has edges facing the grounding means 33, 3, with a spacing therebetween along each edge. This spacing is approximately equal to the distance L6. The distance between the said edges of the metallic layer or the conductive plate 35 is approximately one quarter of the wavelength, at the actual frequency. The metallic layer or conductive plate 35 is electrically insulated from the surrounding conductive parts 1, 3, 33, 32, 2, preferably by a dielectric, filling the space 39, or by any other suitable method of keeping them electrically separated. If a dielectric is used to fill the space it could be a homogeneous dielectric or an inhomogeneous dielectric, such as a foam.

On the second side 1b of the ground plane 1, there is provided a dielectric plate 4 which is attached to the ground plane on one side and carries a feeding conductor 6 on the other.

The feeding conductor 6 extends across the slot 5, preferably perpendicular to the slot 5. The feeding conductor 6 consists in order of a feed portion 8 which is connected to telephone circuitry (not shown), a first line portion 18, possibly a means for matching the impedance of the antenna to a standardized impedance of the circuitry, a second line portion 19 extending across the slot 5, and an open end 9 preferably at a distance from the slot of approximately one quarter of the actual wavelength. The end can alternatively be connected to

the ground plane 1 directly after the feeding conductor have extended across the slot. The feeding conductor 6 can be terminated according to any of the variations of terminating a feeding conductor 6 as described with reference to figs. 8A-D.

In this way, an effective feed is attained. However, there are many alternative configurations of the aperture and the feed line. The ground plane 1 is also connected at a feeding or grounding portion 7 thereof to the telephone circuitry.

Operating as a transmitting antenna the feeding conductor 6 will excite the slot aperture 5, creating an electromagnetic field across the aperture 5. An electromagnetic field is then created between the ground plane and the metallic layer or conductive plate 35. This field is spread perpendicular to the field in both directions towards the grounding means 33, 3 respectively between the metallic layer or conductive plate 35 and the ground plane 1, travels between the metallic layer or conductive plate 35 and the grounding means 33, 3 and further between the metallic layer or conductive plate 35 and the plates 32, 2 to create a field across the radiating slot 34 where the signal is radiated.

The antenna device provided by this construction has a more defined radiating area, which makes it less sensitive to disturbing effects from surrounding parts or components.

As seen in fig. 9B, which is a top view of the antenna device illustrated in fig. 9A, the edges 37 and 38 are parallel, which forms a rectangular slot.

Fig. 9C, is an alternative top view of the antenna device illustrated in fig. 9A. Through varying the width of the slot 34 along the edges 37 and 38 another bandwidth is achieved than in the device having a rectangular slot. In fig. 9C the slot 34 is symmetric to a central axis through the slot, and provided with straight edges. Other forms of the slot are possible, which will give the device different bandwidths.

Referring to fig. 9D an antenna device similar to the one described in connection with fig. 9A is shown in a cross sectional view. The difference is the location of the feeding conductor 6 which is placed between the ground plane 1 and the metallic layer or conductive plate 35.

As illustrated in fig. 9E, which is a side view from the right of the device in fig. 9D, the feed portion 8 of the feeding conductor 6 is arranged near the grounding means 3, which has an opening or aperture through which the feeding conductor 6 extends. The feeding conductor 6 further extends between the ground plane 1 and the metallic layer or conductive plate 35, possibly exhibiting a means for matching the impedance of the antenna to a standardized impedance of the circuitry, continues across the slot, and has an open end 9 preferably at a distance of essentially one quarter of the actual wavelength, from the aperture. The end can alternatively be connected to the ground plane 1. The feeding conductor can be terminated according to any of the variations of terminating a feeding conductor 6 as described with reference to figs. 8A-D.

In this embodiment, the space 39 as well as the space between the grounding means 3 and the feeding conductor 6, can be filled or isolation can be provided for, in accordance with the embodiment described with reference to fig. 9A.

For clarity, fig. 4 shows details of different embodiments to be further explained with reference to fig. 6. Fig. 4 specifically shows patches, grounding means, slots in the patches. Figs. 4A-H show free-standing metal plate embodiments to the left and embodiments with metal on dielectric a carrier to the right. Fig. 4I shows a T-shape element, which includes two patches with a common ground, the patches having different lengths and thus different fundamental frequencies. One of the patches 11 is provided with a slot at the end remote from the grounding. That arrangements facilitates the excitation of the patch in two different modes. Fig. 4C shows two stacked patches with different lengths providing a wider operating frequency

band for the antenna or, in fact, operability within two separated frequency bands. Figs. 4J-K illustrate longitudinal slots in a G-structure and a L-element antenna, wherein the two parts formed may have different dimensions to improve bandwidth. Further, the width of such a slot can be adapted to obtain desired bandwidth and impedance.

Figs. 5A-C illustrate respectively the feeding apertures for an L-element or F-element or G-structure, and for a G-structure, for a T-element. Figs. 5D-E show how the feeding conductor is integrated in the ground plane in the form of a co-planar wave guide with an open end (stub) and a shorted end, respectively.

Figs. 7A-F shows the interrelation of the feeding conductor 6 and the slot. In figs. 7A-E the different combinations of line conductors, transformers, grounded ends, and open ends are shown. Fig. 7F indicated by dashed lines from the side how a feeding conductor, sandwiches in a dielectric between the ground plane and a further conductive plate, may be employed in the invention to couple through a aperture.

Figs. 6A-N show "profiles" of different, advantageous embodiments of the invention. The reference numerals are common for common parts in these figures. Fig. 6A discloses a basic inventive concept, wherein a radiating patch 2 is mounted by a grounding means 3 on ground plane 1 having an aperture in the proximity of the grounding means 3. By feeding the patch, which is basically of quarter wave type, through a non-resonant aperture 5, an improved bandwidth and less sensitivity to an exact feed point are attained.

Single level or stacked T-elements of figs. 6F-L are fed trough two apertures 5, 12 in the ground plane 1. These two apertures are located close to each other in order to obtain correct phasing of the radiating patches. In the case of stacked elements, intermediate level patches are each provided with an aperture for transferring part of the radiation energy from the ground plane aperture(s) to patches at higher levels.

By a G-structure radiator, according to the invention, as illustrated in Figs. 6M-N a compactness is achieved while the distance for the electromagnetic field to travel within the antenna is maintained. Fig. 6M illustrates a G-structure radiator with one aperture slot fed by one single feeding conductor. Fig 6N illustrates a G-structure radiator operable within two separated frequency bands, and is provided with a respective aperture for each band. The apertures are fed by one feeding conductor each.

Referring to figs. 10A-C an antenna is provided with a capacitance between the ground plane 1 and an edge 2b of the patch which is opposite to the edge 2a which is connected to the grounding means 3. By such a use of a capacitance the patch appears electrically to be longer (the distance between 2a and 2b (the edge connected to the grounding means and the opposite edge connected to the capacitance)), which makes it possible to reduce the physical length, and thereby providing a smaller antenna device. The capacitance can include one or more capacitors, as illustrated in fig. 10A. It can alternatively be formed from one elongate plate (layer) or a number of plates (layers) arranged parallel to and at a small distance from the ground plane 1 or the patch 2, as illustrated i figs. 10B and 10C respectively. The plate(s) or layer(s) are connected to the patch 2 or the ground plane 1 respectively by conductor(s) or an elongate conductive plate (layer) or conductive plates (layers) extending essentially perpendicular to the ground plane, as illustrated i figs. 10B and 10C respectively. Preferably the capacitances and their connections are formed by metallic layers on dielectric substrate(s).

It should be noted that the drawings may indicate proportions and dimensions of components of the antenna device. However, e.g., thickness of conductive layers have been exaggerated for clarity. Although, in many embodiments conductive plates have been mentioned, it is understood that it includes the use of conductive layers, possibly attached to dielectric

substrate(s). Although the invention is described by means of the above examples, naturally, a skilled person would appreciate that many other variations than those explicitly disclosed are possible within the scope of the invention.

CLAIMS

1. An antenna device for a portable radio communication device, comprising:

- a conductive first plate (1),
- a conductive second plate (2) being parallel to and spaced by a first spacing D1 apart from the first plate (1) on a first side (1a) thereof and having a first edge (2a),
- a conductive grounding means (3) essentially perpendicular to and interconnecting the first and second plates (1, 2) along a portion of the first edge (2a) of the second plate (2),

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- the first plate (1) being provided with a first aperture (5) at a first distance L1 from the grounding means (3),
- a first conductor (6) extending across the first aperture (5) parallel to and spaced apart from the first plate (1) on a second side thereof (1b),
- the first plate (1) and the first conductor (6) providing first and second feed portions (7, 8), respectively, to be connected to transmitting/receiving circuitry of the radio communication device.

2. An antenna device according to claim 1, wherein

- the first conductor (6) provides the second feed portion (8) at the one side of the first aperture (5) and has on the other side an open end (9) at essentially one quarter of a wavelength.

3. An antenna device according to claim 1, wherein

- the first conductor (6) provides the second feed portion (8) at the one side of the first aperture (5) and is connected on the other side to the first plate (1) essentially immediately by a second conductor (10).

4. An antenna device according to any preceding claim, wherein

- the second plate (2) is provided with a third aperture

(13) at a third distance L3 from the grounding means (3) so as to facilitate excitation of the second plate (2) in two different resonant modes.

5. An antenna device according to any preceding claim, wherein
- the antenna device further comprises a conductive third plate (11) being parallel to and spaced apart from the first plate (1) on the first side thereof (1b),
- the third plate (11) being connected to the second plate at the first edge (2a) and extends from it in a direction opposite to that of the second plate (2),
- the first plate is provided with a second aperture (12) at a second distance L2 from the grounding means (3) at a side thereof opposite to that of the first aperture,
- the first conductor (6) extending across the second aperture as well as across the first aperture (5).

6. An antenna device according to claim 5, wherein
- the third plate (11) is provided with a fourth aperture (14) at a fourth distance L4 from the grounding means (3) so as to facilitate excitation of the third plate (11) in two different resonant modes.

7. An antenna device according to any preceding claim, wherein
- the antenna device comprises at least one second level conductive plate (15, 16) being parallel to and spaced apart by a second spacing D2, greater than the first spacing D1, from the first plate (1) on the first side thereof,
- the second level conductive plate(s) (15, 16) are stacked on the second and/or third plates (2, 11) and connected by an extension (3a) of the grounding means (3),
- the second and/or third conductive plate(s) has a fifth aperture (22, 23) in a position providing a radiation feed-through from the first and/or second apertures.

8. An antenna device according to claim 7, wherein
- the antenna device comprises at least one third, or

higher, level conductive plate (20, 21) being parallel to and spaced apart by a third spacing D3, greater than the second spacing D2, from the first plate (1) on the first side thereof,

- the third level conductive plate(s) (20, 21) are stacked on the second level conductive plate(s) (15, 16) and connected by an extension (3b) of the grounding means (3),
- the second level conductive plate(s) have a seventh aperture (22, 23) in a position providing a radiation feed-through from the first and/or second apertures.

9. An antenna device according to claim 7 or 8, wherein

- at least one of the second level, or higher, conductive plates (15, 16, 20, 21) is provided with a sixth aperture (24, 25, 26, 27) at a fifth distance L5 from the grounding means (3) so as to facilitate excitation of the respective conductive plate (15, 16, 20, 21) in two different resonant modes.

10. An antenna device according to claim 1, 2, or 3, wherein

- another structure including a fourth conductive plate and a second grounding means corresponding to the second plate and the first grounding means, respectively, is arranged so as to form, together with a portion of the first conductive plate, a side profile having the form of the capital letter "G" so as to reduce the overall size.

11. An antenna device according to claim 1, 2, or 3, wherein

- another structure including a fourth conductive plate, a second grounding means, and an eighth aperture corresponding to the second plate, the first grounding means, and the first aperture, respectively, is arranged so as to form, together with a portion of the first conductive plate, a side profile having the form of the capital letter "G" so as to facilitate operation within two separated frequency bands.

12. An antenna device according to any of claims 1-3, wherein
- the conductive first plate (1) is provided with a third grounding means (33), on its first side and opposite to the first grounding means (3),
- the aperture (5) is located between the first grounding means (3) and the third grounding means (33),
- a sixth conductive plate (32) is interconnected at a first edge to the conductive first plate (1) via the third grounding means (33),
- the second and sixth conductive plates (2,32) are extending from their respective grounding means (3, 33) towards each other, leaving a spacing (34) between the edges that are facing each other, which spacing (34) can be constant or vary along the edges,
- a conductive layer or conductive seventh plate (35) is arranged between the conductive first, second and sixth plates (1, 2, 32).

13. An antenna device according to claim 12, wherein
- the second and sixth conductive plates (2, 32) are arranged in the same plane and are parallel to the conductive first plate (1) and the conductive layer or conductive seventh plate (35),
- the first and third grounding means (3, 33) are arranged parallel to each other at opposed edges of the conductive first plate (1),
- the aperture (5) is parallel to the grounding means (3, 33).

14. An antenna device according to any preceding claim, wherein
- the first conductor includes a transmission line being at least one in a group consisting of a microstrip line, a stripline, and a coplanar wave guide.

15. An antenna device according to any preceding claim, wherein
- the first aperture (5) has essentially a shape of one in a group consisting of a rectangle, a circle, an oval, an ellipse, a bow tie, and an arc.

16. An antenna device according to any preceding claim, wherein
- the first conductor (6) includes a quarter wave transformer (17) and at least one transmission line segment (18, 19).

17. An antenna device according to any preceding claim, wherein
- the second, third, fourth and/or further conductive plates are each provided with at least one dividing slot that forms by two or more substantially coextending plate portions.

18. An antenna device according to any preceding claim, wherein
- a capacitance (40) is arranged or formed between the first plate (1) and the second plate (2) at or close to a second edge opposite to the first edge (2a) of the second plate, and/or a capacitance (40) is arranged or formed between the first plate (1) and the third plate (11) at or close to a second edge of the third plate opposite to the edge connected to the first edge (2a) of the second plate (2).

19. An antenna device for a portable radio communication device, comprising:
- a conductive first plate (1) having first and second surfaces,
- a conductive second plate (2) being parallel to and spaced by a first spacing D1 apart from the first plate (1) on a first side (1a) thereof, facing said first surface, and having a first edge (2a),
- a conductive first grounding means (3) essentially perpendicular to and interconnecting the first and second plates (1, 2) along a portion of the first edge (2a) of the second plate (2),

characterized by
- the first plate (1) being provided with a first aperture (5) at a first distance L1 from the grounding means (3),
- a first conductor (6) extending across the first aperture (5),

- the first conductor (6) is located on the same side of said second surface as the conductive second plate,
- the first plate (1) and the first conductor (6) providing first and second feed portions (7, 8), respectively, to be connected to transmitting/receiving circuitry of the radio communication device.

20. An antenna device according to claim 19, wherein
- the first conductor (6) extends across the first aperture (5) spaced apart from the first plate (1) on the first side (1a) thereof.

21. An antenna device according to claim 20, wherein
- the first conductor (6) extends through an opening or aperture (31) in the first grounding means (3),
- the first conductor (6) and the first grounding means (3) are electrically insulated from each other.

22. An antenna device according to claim 19, wherein
- the first conductor (6) is arranged in the same plane as the first plate (1) which has an slot in order to leave a spacing between the first plate and the conductor, said spacing extending on both sides of the first conductor at least from the feed portion to the aperture.

23. An antenna device according to any of claims 19-22, wherein
- the first plate (1) is provided with a second aperture (12) at a distance from the grounding means (3),
- a second conductor (6) extending across the second aperture (12) parallel to and spaced apart from the first plate (1) on a second side thereof (1b),
- the second conductor (6) providing a third feed portion (8), to be connected to transmitting/receiving circuitry of the radio communication device.

24. An antenna device according to any of claims 19-23, wherein
- the first conductor (6) provides the second feed portion (8) at the one side of the first aperture (5) and has on

the other side an open end (9) at essentially one quarter of a wavelength.

25. An antenna device according to any of claims 19- 23, wherein
- the first conductor (6) provides the second feed portion (8) at the one side of the first aperture (5) and is connected on the other side to the first plate (1) essentially immediately by a second conductor (10).

26. An antenna device according to any of claims 19-25, wherein
- the second plate (2) is provided with a third aperture (13) at a third distance L3 from the grounding means (3) so as to facilitate excitation of the second plate (2) in two different resonant modes.

27. An antenna device according to any of claims 19-26, wherein
- the antenna device further comprises a conductive third plate (11) being parallel to and spaced apart from the first plate (1) on the first side thereof (1b),
- the third plate (11) being connected to the second plate at the first edge (2a) and extends from it in a direction opposite to that of the second plate (2),
- the first plate is provided with a second aperture (12) at a second distance L2 from the grounding means (3) at a side thereof opposite to that of the first aperture,
- the first conductor (6) extending across the second aperture as well as across the first aperture (5).

28. An antenna device according to claim 27, wherein
- the third plate (11) is provided with a fourth aperture (14) at a fourth distance L4 from the grounding means (3) so as to facilitate excitation of the third plate (11) in two different resonant modes.

29. An antenna device according to any of claims 19-28, wherein
- the antenna device comprises at least one second level conductive plate (15, 16) being parallel to and spaced

apart by a second spacing D2, greater than the first spacing D1, from the first plate (1) on the first side thereof,

- the second level conductive plate(s) (15, 16) are stacked on the second and/or third plates (2, 11) and connected by an extension (3a) of the grounding means (3),
- the second and/or third conductive plate(s) has a fifth aperture (22, 23) in a position providing a radiation feed-through from the first and/or second apertures.

30. An antenna device according to claim 29, wherein

- the antenna device comprises at least one third, or higher, level conductive plate (20, 21) being parallel to and spaced apart by a third spacing D3, greater than the second spacing D2, from the first plate (1) on the first side thereof,
- the third level conductive plate(s) (20, 21) are stacked on the second level conductive plate(s) (15, 16) and connected by an extension (3b) of the grounding means (3),
- the second level conductive plate(s) have a seventh aperture (22, 23) in a position providing a radiation feed-through from the first and/or second apertures.

31. An antenna device according to claim 29 or 30, wherein

- at least one of the second level, or higher, conductive plates (15, 16, 20, 21) is provided with a sixth aperture (24, 25, 26, 27) at a fifth distance L5 from the grounding means (3) so as to facilitate excitation of the respective conductive plate (15, 16, 20, 21) in two different resonant modes.

32. An antenna device according to any of claims 19- 25, wherein

- another structure including a fourth conductive plate and a second grounding means corresponding to the second plate and the first grounding means, respectively, is arranged so as to form, together with a portion of the

first conductive plate, a side profile having the form of the capital letter "G" so as to reduce the overall size.

33. An antenna device according to any of claims 19- 25, wherein

- another structure including a fourth conductive plate, a second grounding means, and an eighth aperture corresponding to the second plate, the first grounding means, and the first aperture, respectively, is arranged so as to form, together with a portion of the first conductive plate, a side profile having the form of the capital letter "G" so as to facilitate operation within two separated frequency bands.

34. An antenna device according to any of claims 19-25, wherein

- the conductive first plate (1) is provided with a third grounding means (33), on its first side and opposite to the first grounding means (3),
- the aperture (5) is located between the first grounding means (3) and the third grounding means (33),
- a sixth conductive plate (32) is interconnected at a first edge to the conductive first plate (1) via the third grounding means (33),
- the second and sixth conductive plates (2, 32) are extending from their respective grounding means (3,33) towards each other, leaving a spacing (34) between the edges that are facing each other, which spacing (34) can be constant or vary along the edges,
- a conductive layer or conductive seventh plate (35) is arranged between the conductive first, second and sixth plates (1, 2, 32).

35. An antenna device according to claim 34, wherein

- the second and sixth conductive plates (2, 32) are arranged in the same plane and are parallel to the conductive first plate (1) and the conductive layer or conductive seventh plate (35),
- the first and third grounding means (3, 33) are arranged

parallel to each other at opposed edges of the conductive first plate (1),

- the aperture (5) is parallel to the grounding means (3, 33).

36. An antenna device according to any of claims 19-35, wherein

- the first conductor includes a transmission line being at least one in a group consisting of a microstrip line, a stripline, and a coplanar wave guide.

37. An antenna device according to any of claims 19-36, wherein

- the first aperture (5) has essentially a shape of one in a group consisting of a rectangle, a circle, an oval, an ellipse, a bow tie, and an arc.

38. An antenna device according to any of claims 19-37, wherein

- the first conductor (6) includes a quarter wave transformer (17) and at least one transmission line segment (18, 19).

39. An antenna device according to any of claims 19-38, wherein

- the second, third, fourth and/or further conductive plates are each provided with at least one dividing slot that forms by two or more substantially coextending plate portions.

40. An antenna device according to any of claims 19-39, wherein

- a capacitance (40) is arranged or formed between the first plate (1) and the second plate (2) at or close to a second edge opposite to the first edge (2a) of the second plate, and/or a capacitance (40) is arranged or formed between the first plate (1) and the third plate (11) at or close to a second edge of the third plate (11) opposite to the edge connected to the first edge (2a) of the second plate.

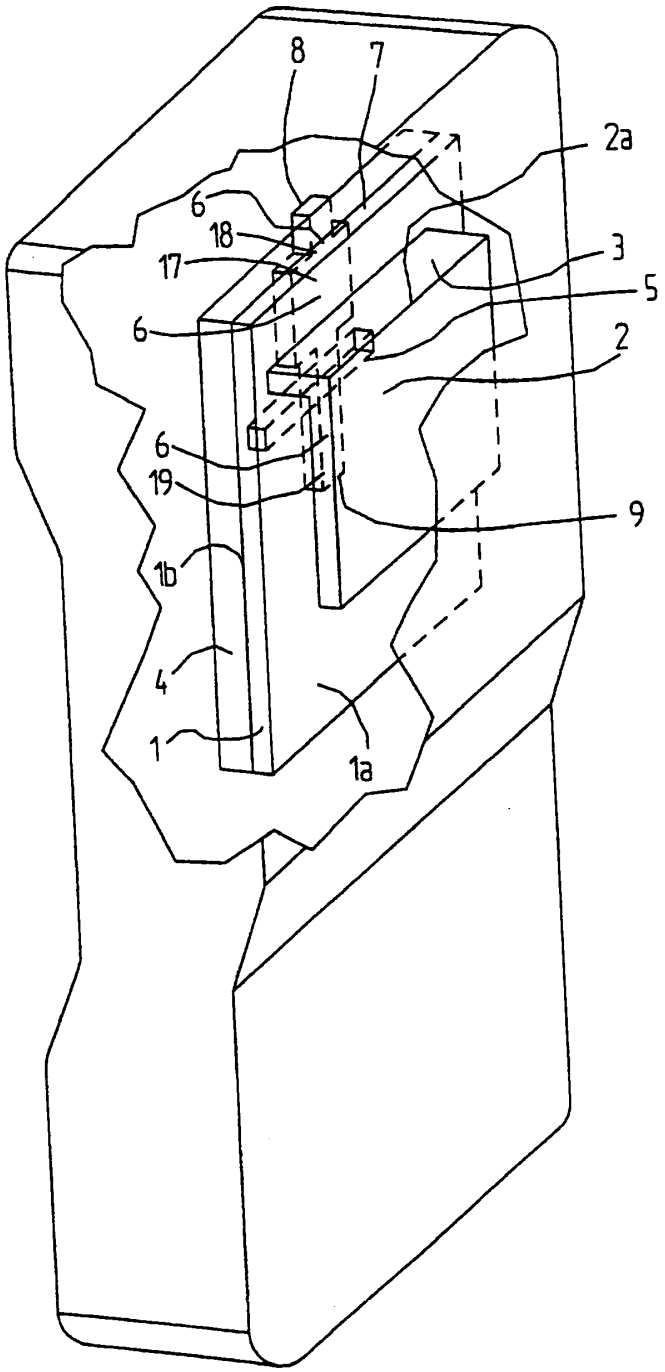


Fig. 1.

Fig. 2A.

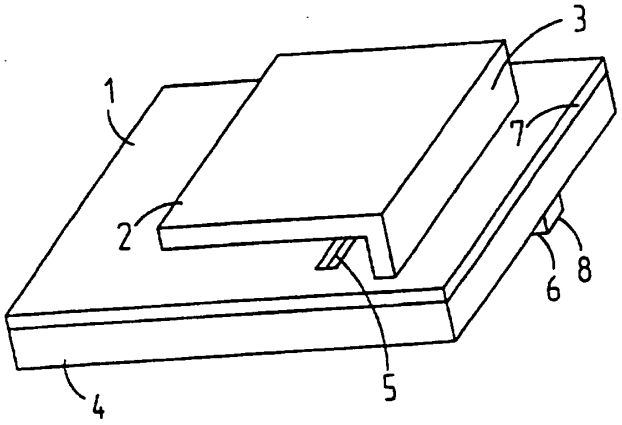
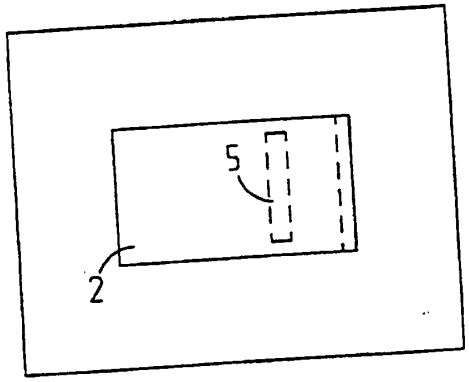


Fig. 2B.



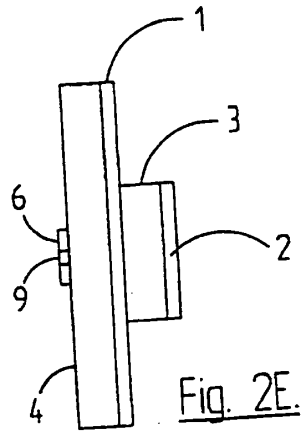


Fig. 2E.

Fig. 2C.

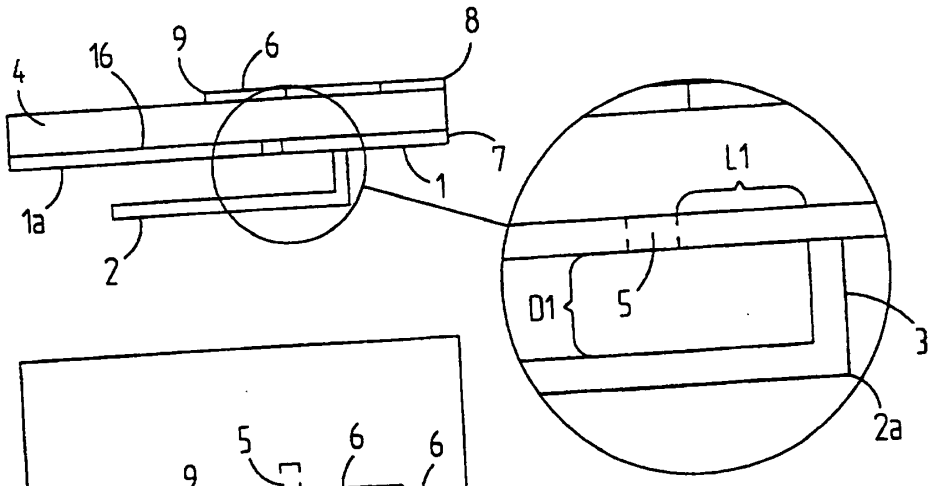
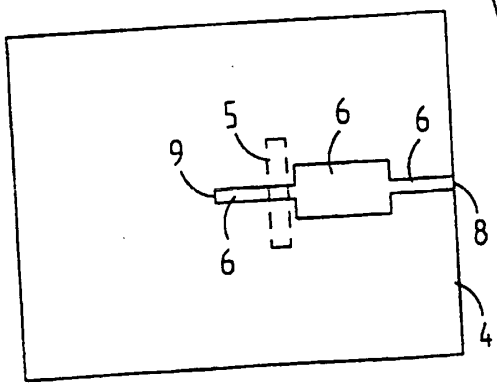


Fig. 2D.



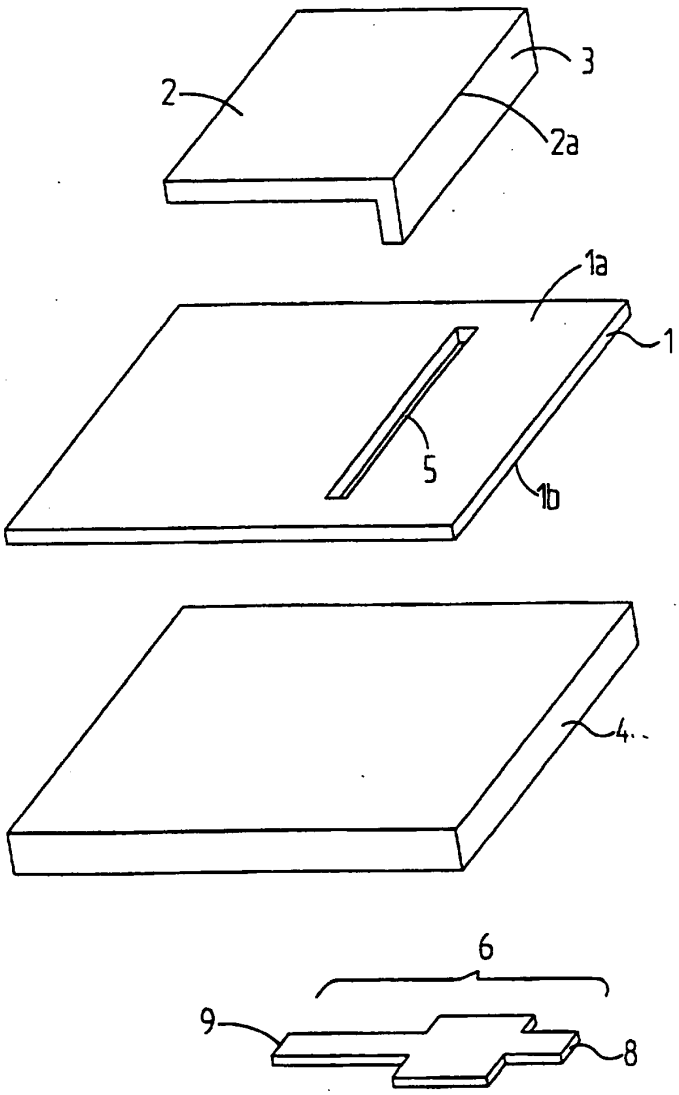


Fig. 3.

Fig. 4A.

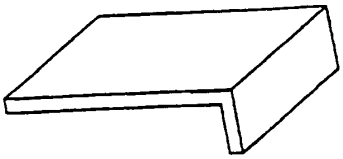


Fig. 4B.

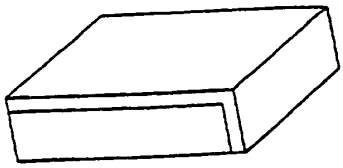


Fig. 4C.

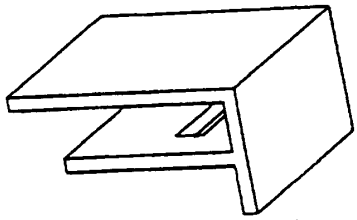


Fig. 4D.

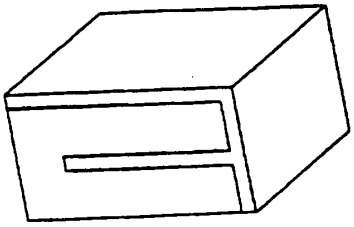


Fig. 4E.

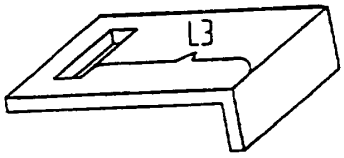


Fig. 4F.

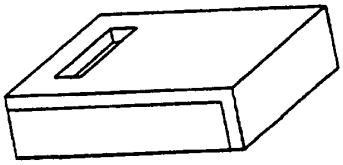


Fig. 4G.

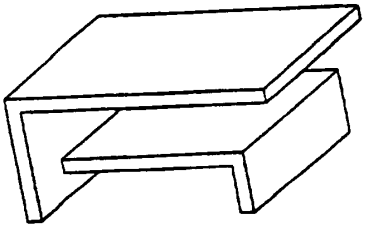


Fig. 4H.

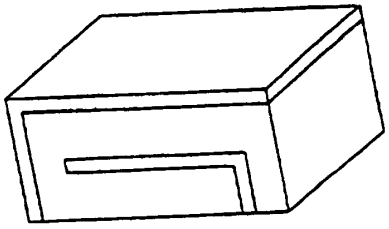


Fig. 4I.

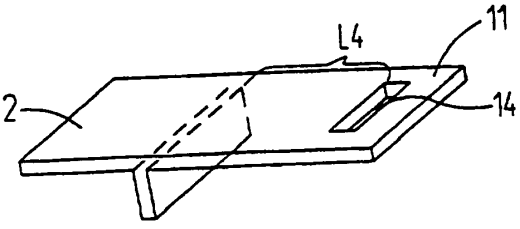


Fig. 4J.

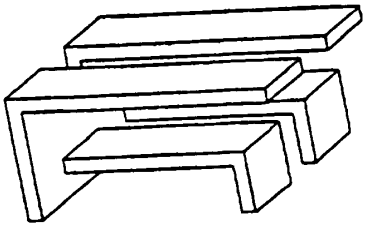


Fig. 4K.

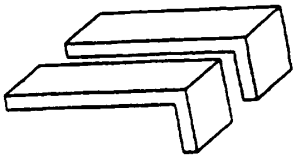


Fig. 5A.

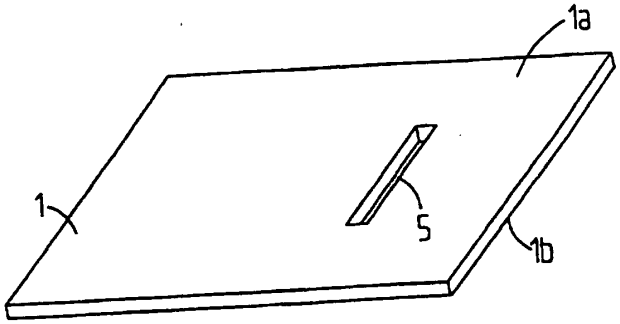


Fig. 5B.

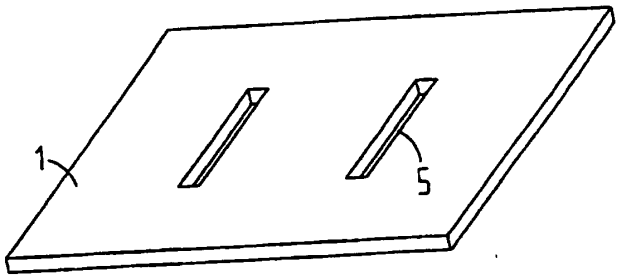


Fig. 5C.

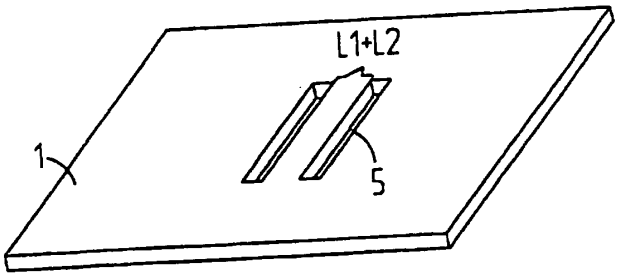


Fig. 5D.

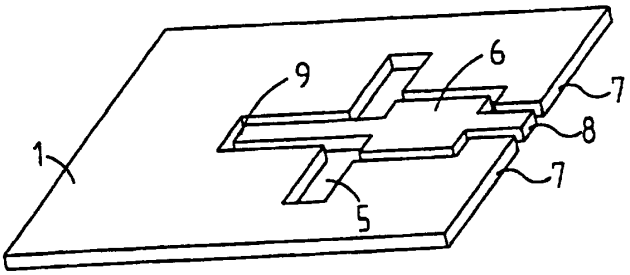


Fig. 5E.

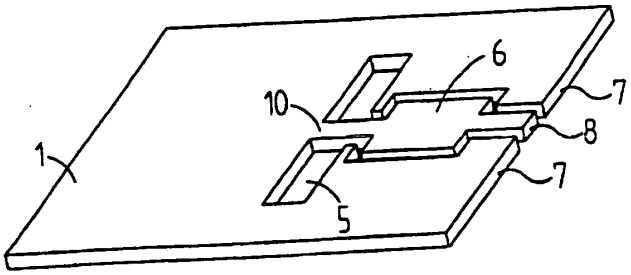


Fig. 6A.

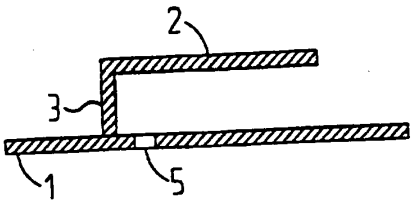


Fig. 6B.

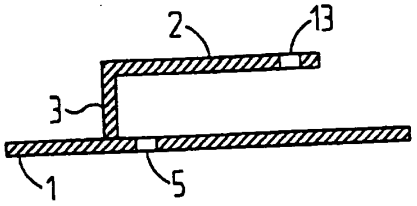


Fig. 6C.

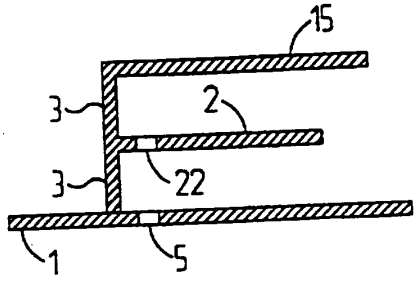


Fig. 6D.

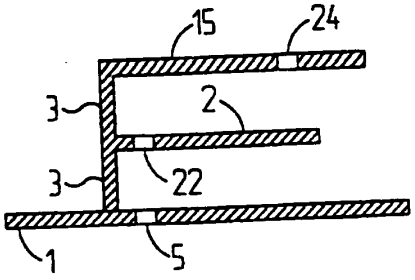


Fig. 6E.

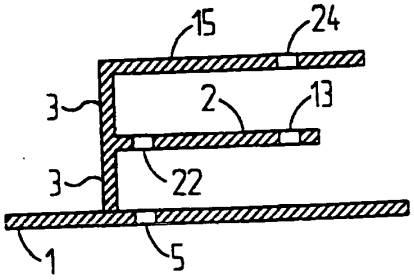


Fig. 6F.

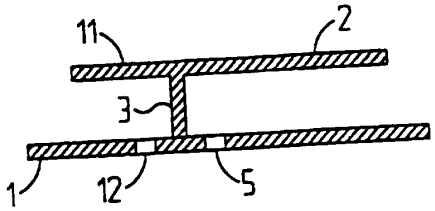


Fig. 6G.

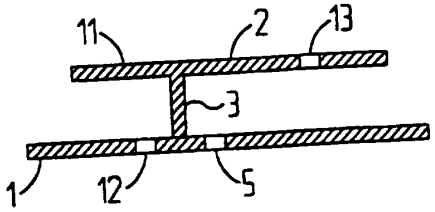


Fig. 6H.

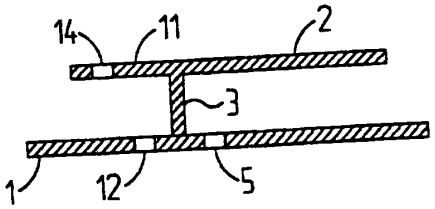


Fig. 6I.

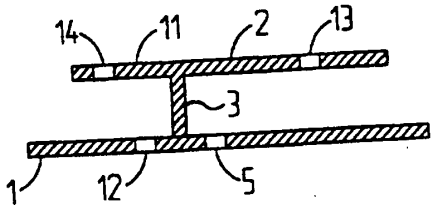
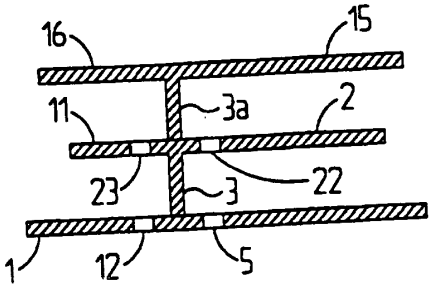


Fig. 6J.



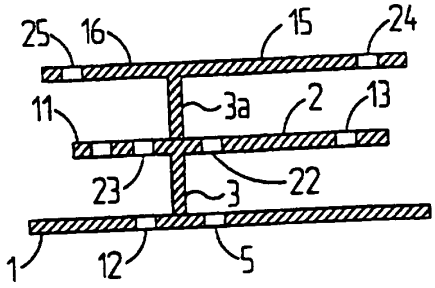


Fig. 6K.

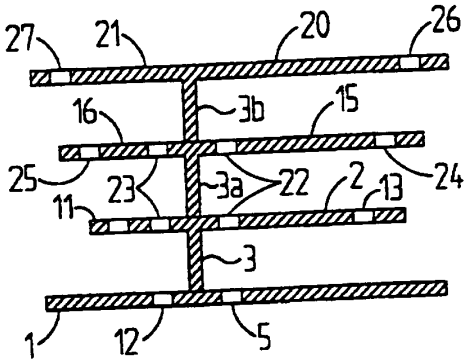


Fig. 6L.

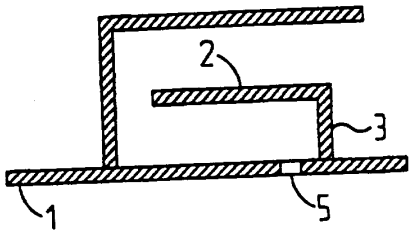


Fig. 6M.

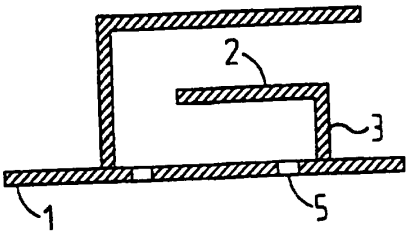


Fig. 6N.

Fig. 7A.

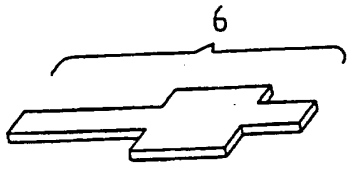


Fig. 7B.

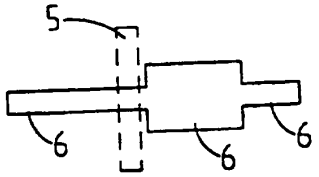


Fig. 7C.

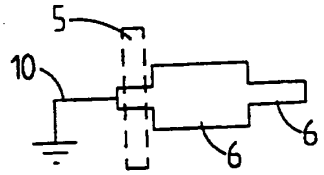


Fig. 7D.

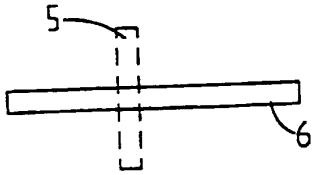


Fig. 7E.

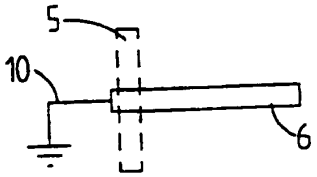
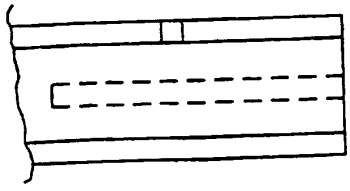


Fig. 7F.



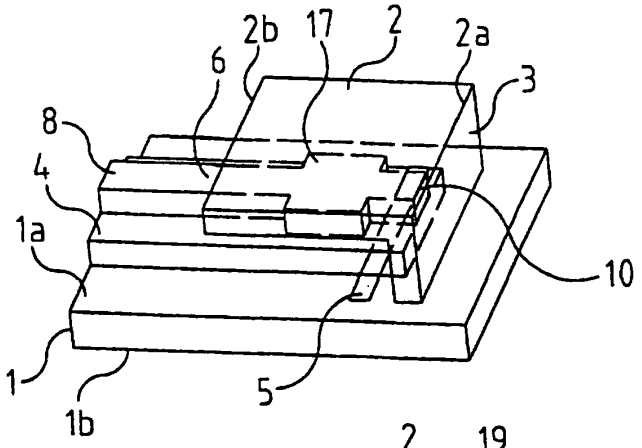


Fig. 8A.

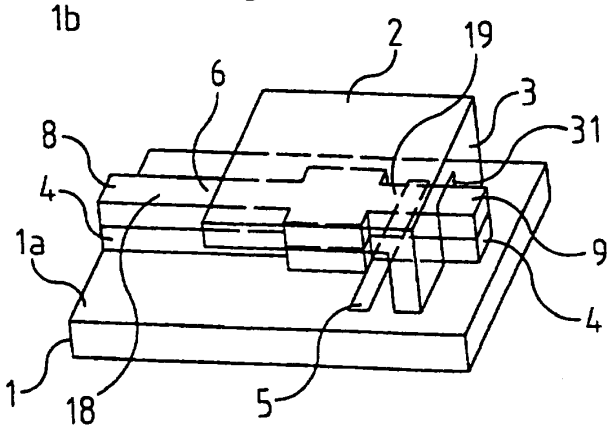


Fig. 8B.

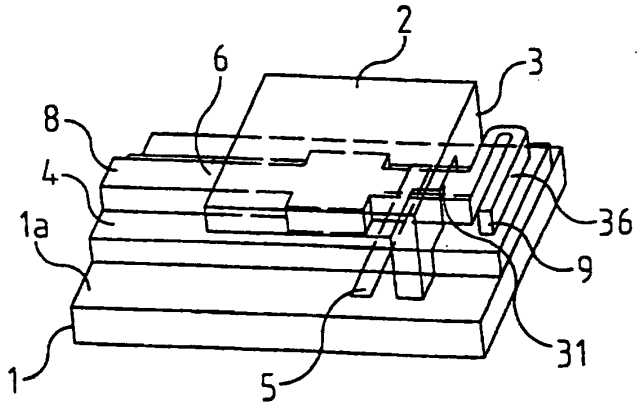


Fig. 8C.

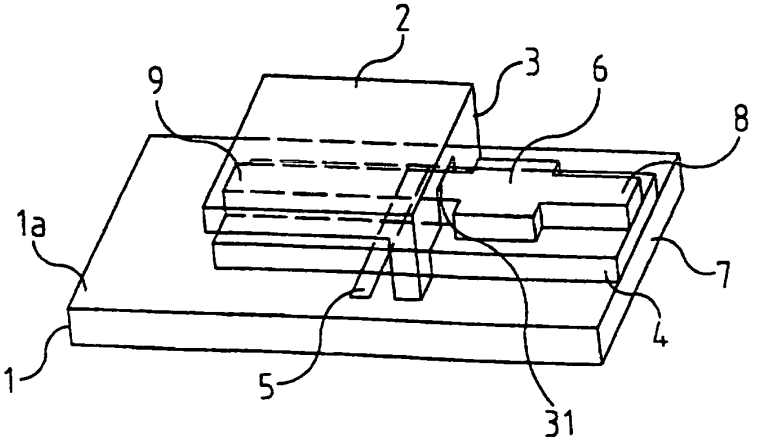


Fig. 8D.

Fig. 9A.

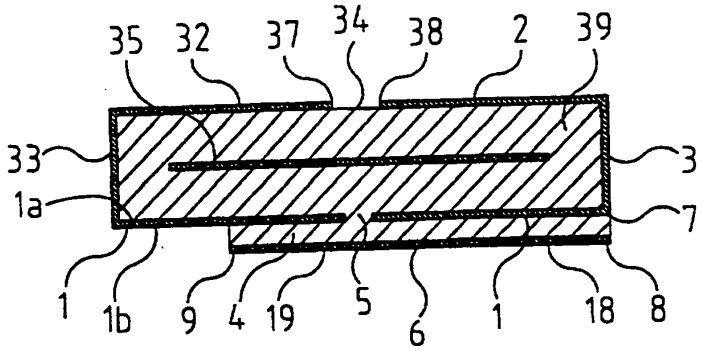


Fig. 9B.

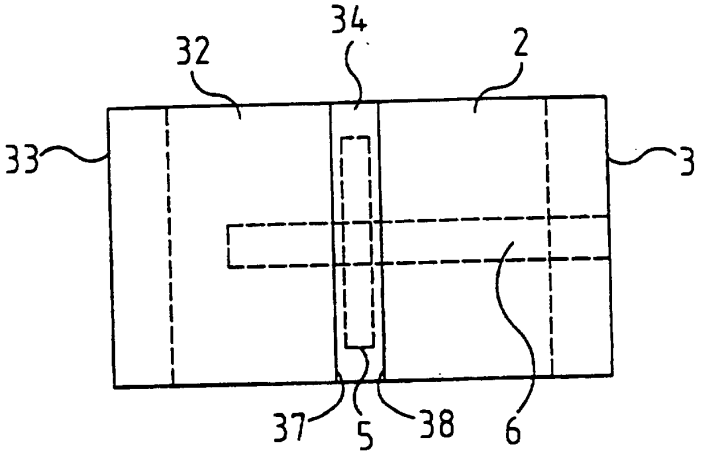
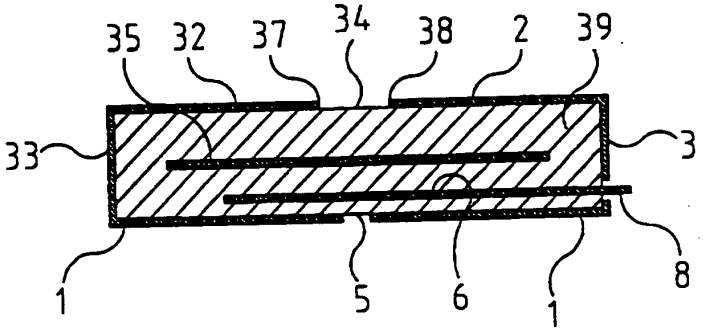
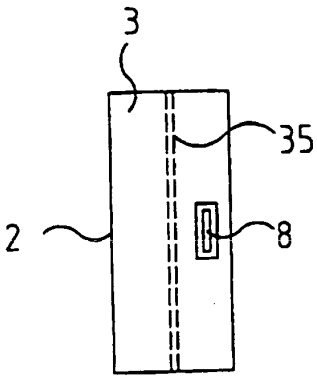


Fig. 9D.





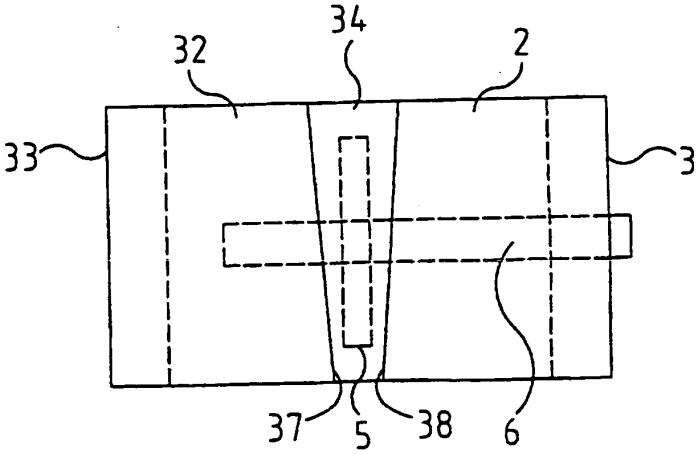


Fig. 9E.

Fig. 9C.

Fig. 10A.

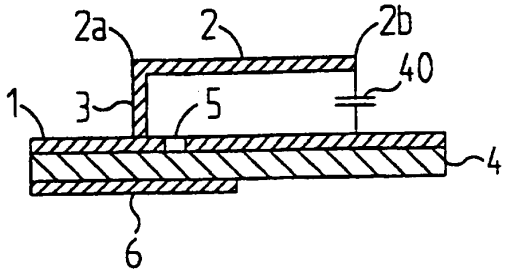


Fig. 10B.

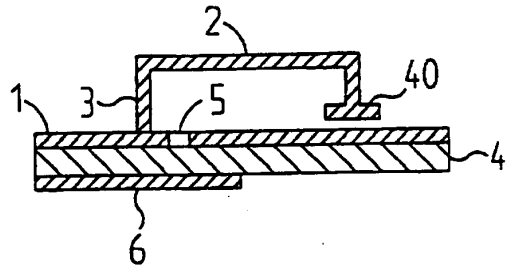
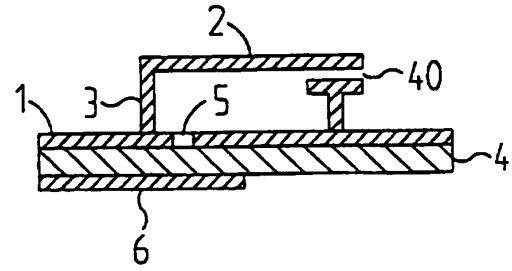


Fig. 10C.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00815

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01Q 9/04, H01Q 1/24
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0177362 A2 (NEC CORPORATION), 9 April 1986 (09.04.86), abstract --	1-40
A	US 5365246 A (JOSEF RASINGER ET AL), 15 November 1994 (15.11.94), cited in the description --	1-40
A	US 5355143 A (JEAN F. ZüRCHER ET AL), 11 October 1994 (11.10.94), cited in the description -- --------	1-40

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 Sept 1997	12 -09- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Rune Bengtsson Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

06/08/97

International application No.
PCT/SE 97/00815

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